Age-Specific and Sex-Specific Differences in Diagnostic Accuracy of High-Resolution Ultrasonography for Acute Appendicitis

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Objective: To evaluate the diagnostic capability of high-resolution ultrasonography (HRUS) for clinically suspected acute appendicitis in patients of different sex and age presenting with acute right lower quadrant pain at the Emergency Department of Tri-Service General Hospital, Taipei, Taiwan.

Materials and Methods: The study included 734 consecutive patients (366 males and 368 females) in whom acute appendicitis was clinically suspected and evaluated using HRUS between January 1997 and November 1999. Patients were classified into two groups by sex, and further classified into four age groups (I = 0–17 yr; II = 18–45 yr; III = 46–60 yr; IV = > 60 yr) for categorical analysis. We retrospectively reviewed and compared the patients' HRUS images with their operative findings and histologic results to evaluate the overall age-specific and sex-specific diagnostic ability of HRUS for acute appendicitis. The chi-square test was used for categorical data analysis. Comparative analysis of our data with previously published data on the correlation between the prevalence of acute appendicitis and sonographic diagnosis of acute appendicitis was performed using linear regression.

Results: The overall accuracy, sensitivity, specificity, positive and negative predictive rates were 89%, 87%, 90%, 89% and 88%, respectively. Age-specific analysis revealed a statistically significant difference in diagnostic accuracy between age groups II and III among women (85% vs 96%, respectively; $p < 0.05$). Sex-specific analysis of age group II showed higher sensitivity (90% vs 77%; $p < 0.05$) and positive predictive values (89% vs 77%; $p < 0.05$) in women than in men, respectively. In age group III, the accuracy of HRUS was higher in men than in women (96% vs 84%, respectively; $p < 0.05$). The negative predictive value and overall diagnostic accuracy were negatively correlated to the prevalence of acute appendicitis.

Conclusion: The value of HRUS for the diagnosis of acute appendicitis varied among different age and sex groups. The prevalence of acute appendicitis was

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negatively correlated with the negative predictive value and overall diagnostic accuracy of HRUS for acute appendicitis.

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KEY WORDS: • acute appendicitis • high-resolution ultrasonography (HRUS)

Introduction

Acute appendicitis is the most commonly encountered entity of acute abdomen requiring emergency surgery in the Emergency Department of Tri-Service General Hospital in Taipei, Taiwan. As the application of high-resolution ultrasonography (HRUS) has developed, several authors have reported high rates of accuracy for the sonographic diagnosis of clinically suspected acute appendicitis. Some authors have reported even higher rates of diagnostic accuracy in pediatric patient groups. Nonetheless, differences in diagnostic accuracy of sonography in acute appendicitis between the sexes and in different age groups have not been reported. In addition, a correlation between the prevalence of acute appendicitis and the results of sonography for diagnosis of acute appendicitis has not been documented until now. The aims of this study were to evaluate the overall results of age-specific and sex-specific HRUS diagnoses of acute appendicitis and to verify the correlation between the prevalence and sonographic results for acute appendicitis.

Materials and Methods

Between January 1997 and November 1999, 774 patients underwent HRUS examination for clinically suspected acute appendicitis in the Emergency Department of Tri-Service General Hospital. Of those, 734 were included in this study: 366 (50%) males and 368 (50%) females with a mean age of 34 years (range, 0–89 yr). Forty patients were excluded from this study because they did not require surgery and were not monitored in our hospital.

All ultrasonography was performed using 3.5-MHz and 7.0-MHz linear array transducers (Acuson 128XP/10, Mountain View, CA, USA). Before examining the appendix, we routinely scanned other abdominal organs, including the liver, gallbladder and biliary system, pancreas, spleen and kidneys using a 3.5-MHz linear array transducer. Attention was also paid to the detection of any extraluminal fluid collection in the dependent portion of the right lower abdomen and pelvis.

Using a 7.0-MHz linear array transducer, the appendix was investigated using the graded compression technique introduced by Puylaert in 1986 [1]. A positive sonographic result was recorded when an aperistaltic, noncompressible and sausage-like structure with a diameter ≥ 7 mm arising from the base of the cecum was seen. Acute appendicitis with perforation was suspected if there was loculated pericecal fluid, prominent adjacent pericecal fat of more than 10 mm in thickness or loss of the echogenic submucosal layer of the appendix, as reported by Borushok et al in 1990 [2].

Patients with positive sonographic results underwent immediate appendectomy. Patients with HRUS results negative for acute appendicitis were treated differently, according to their clinical conditions and other sonographic findings. Those with strong clinical evidence of acute appendicitis underwent appendectomy in spite of negative sonographic results. Those with surgical conditions other than acute appendicitis underwent appropriate surgical procedures according to their pathology. Those without definitive evidence of a condition requiring surgery received conservative treatment and were monitored in our outpatient department for 3 days to 2 years after discharge.

Histologically, acute appendicitis was defined as polymorphonuclear infiltration of the entire appendiceal wall, with or without necrosis or rupture. The presence of fecalith did not contribute to the diagnosis of acute appendicitis. Several histologic findings, including congestion of the mucosal layer of the appendix, lymphoid hyperplasia and periappendicitis (inflammation of the serosa only), were also excluded from the diagnosis of acute appendicitis.

HRUS results were correlated to the operative and histologic results and medical charts to evaluate

the diagnostic capability of HRUS for acute appendicitis. Definitions of sensitivity, specificity, positive predictive rate, negative predictive rate and accuracy of HRUS in diagnosing acute appendicitis are given in Table 1. Sex-specific analysis of all patients was performed according to patient gender. An age-specific analysis was also done for four clinically relevant age groups: group I, children and adolescents (0–17 yr); group II, young adults (18–45 yr); group III, adults (46–60 yr); and group IV, the elderly (> 60 yr). The chi-square test was used for the analysis of categorical data. Probability values of less than 0.05 were considered statistically significant.

Using linear regression, our data were compared to prior documented studies to access the correlation between the prevalence of acute appendicitis and sonographic diagnosis of acute appendicitis.

Results

There were 734 patients (366 males and 368 females) in the study group, with ages ranging from 0 to 89 years (mean, 34 yr). The overall age-specific and sex-specific HRUS results are listed in Table 2. The details of false-positive and false-negative results on HRUS study are summarized in Tables 3 and 4, respectively. Details of sonographic results of 14 documented, related reports were compared with those of our study as shown in Table 5 [1, 3–15].

In our study, acute appendicitis was confirmed histologically in 351 of 734 patients (prevalence,

Table 1. Use of high-resolution ultrasound (HRUS) results to calculate sensitivity, specificity, positive predictive rate, negative predictive rate and diagnostic accuracy in acute appendicitis

Final diagnosis	HRUS results (+)	HRUS results (–)
Acute appendicitis	True positive (TP)	False negative (FN)
Not acute appendicitis	False positive (FP)	True negative (TN)

Calculations: Sensitivity = TP/(TP+FN); Specificity = TN/(TN+FP); Positive predictive rate = TP/(TP+FP); Negative predictive rate = TN/(TN+FN); Diagnostic accuracy = (TP+TN)/(TP+TN+FP+FN).

Table 2. Sex-specific and age-specific analysis of high-resolution ultrasound (HRUS) in diagnosing acute appendicitis

Group (age)	Total	TP	TN	FP	FN	Sn (%)	Sp (%)	PPR (%)	NPR (%)	Ac (%)	P	PR (%)
Total	734	306	345	38	45	87	90	89	88	89	113	32
I (0–17 yr)	112	62	39	5	6	91	89	93	87	90	34	50
II (18–45 yr)	440	164	220	29	27	86	88	85	89	87	40	21
III (46–60 yr)	90	44	39	1	6	88	98	98	87	92	15	31
IV (> 60 yr)	92	36	47	3	6	86	94	92	89	90	24	57
Males	366	186	142	17	21	90	88	90	87	89	57	28
I (0–17 yr)	57	39	15	1	2	95	94	98	88	95	18	44
II (18–45 yr)	234	114	94	14	12	90	87	89	89	89	21	17
III (46–60 yr)	37	18	14	1	4	82	93	95	78	86	7	32
IV (> 60 yr)	38	15	19	1	3	83	95	94	86	89	11	61
Females	368	120	203	21	24	83	90	85	89	88	56	39
I (0–17 yr)	55	23	24	4	4	85	86	85	86	85	16	59
II (18–45 yr)	206	50	126	15	15	77	89	77	89	85	19	29
III (46–60 yr)	53	26	25	0	2	93	100	100	93	96	8	29
IV (> 60 yr)	54	21	28	2	3	88	93	91	90	91	13	54

TP = true positive; TN = true negative; FP = false positive; FN = false negative; Ac = accuracy; P = number of perforations; PR = perforation rate. See Table 1 for calculations of sensitivity (Sn), specificity (Sp), positive predictive rate (PPR), negative predictive rate (NPR) and diagnostic accuracy.

Table 3. Patients with false-positive sonographic results categorized by sex and age

Age group	Sex	Age (yr)	Patient no.	Pathology of appendix	Diameter of appendix specimen (mm)	WBC x 1,000 (/μL)	N/L ratio (%)	Other pathology
I	M	6	1	Fecalith	6	28.8	78	–
	F	5	1	Lymphoid hyperplasia	7	11.1	63	–
	F	6	2	Lymphoid hyperplasia	NA	16.2	72	Serositis of cecum
	F	8	3	Lymphoid hyperplasia	NA	11.2	75	Tumor of ascending colon near ileocecal valve
	F	17	4	Lymphoid hyperplasia	5	10.6	81	
II	M	18	1	Lymphoid hyperplasia	NA	11.3	73	Adenitis
	M	19	2	Lymphoid hyperplasia	5	15.5	68	–
	M	20	3	Fecalith	7	13.9	80	–
	M	21	4	Lymphoid hyperplasia	5	9	63	–
	M	21	5	Lymphoid hyperplasia	6	11.4	75	–
	M	22	6	Lymphoid hyperplasia	NA	NA	NA	–
	M	23	7	Lymphoid hyperplasia	NA	7	60	–
	M	25	8	Fecalith	NA	6.2	59	–
	M	27	9	Periappendicitis	12	18.1	89	–
	M	28	10	Fecalith	10	12.7	NA	–
	M	33	11	Periappendicitis	5	15.9	86	Foreign body with ruptured terminal ileum and abscess
	M	33	12	Fecalith	NA	9.1	NA	Lymphoma of terminal ileum
	M	36	13	Lymphoid hyperplasia	10	9.7	66	Cecal diverticulitis
	M	44	14	Fecalith	10	9.2	72	–
	F	18	1	Lymphoid hyperplasia	10	9.5	43	–
	F	19	2	Fecalith	5	7.7	NA	–
	F	23	3	Lymphoid hyperplasia	5	11.3	85	–
	F	23	4	Lymphoid hyperplasia	6	12	80	–
	F	25	5	Fecalith	6	6.8	72	–
	F	26	6	Periappendicitis; fecalith	5	15.4	81	Cecal diverticulitis
	F	28	7	Lymphoid hyperplasia	10	11.7	89	–
	F	29	8	Fecalith	6	7.1	80	–
	F	30	9	Lymphoid hyperplasia	8	11.3	82	Pelvic inflammatory disease; intestinal obstruction
	F	34	10	Periappendicitis	5	11.4	89	Endometrioma, right ovary
	F	38	11	Fecalith	5	18.6	87	–
	F	38	12	Periappendicitis; lymphoid hyperplasia	12	9.4	NA	–
	F	40	13	Congestion	5	8.3	79	Cecal diverticulitis
	F	40	14	Fecalith	5	NA	NA	–
	F	42	15	Lymphoid hyperplasia	NA	7.2	57	–
III	M	48	1	Lymphoid hyperplasia	8	13.1	82	–
IV	M	67	1	Lymphoid hyperplasia	7	12.7	82	Chronic cholecystitis with acute onset and rupture
	F	61	1	Lymphoid hyperplasia	4	14.8	78	–
	F	66	2	Mucinous cystadenocarcinoma	12	14	88	–

N/L = neutrophil/lymphocyte ratio; WBC = white blood cell; NA = not available.

Table 4. Patients with false-negative sonographic results categorized by sex and age

Age group	Sex	Age (yr)	Patient no.	Pathology of appendix	Perforation	Diameter of appendix specimen (mm)	WBC x 1,000 (/μL)	N/L ratio (%)
I	M	4	1	Acute suppurative appendicitis	–	5	22.5	93
	M	8	2	Acute suppurative appendicitis	+	7	24.3	86
	F	4	1	Acute suppurative appendicitis	–	15	20.9	89
	F	9	2	Acute suppurative appendicitis	+	8	15.4	88
	F	10	3	Acute suppurative appendicitis	–	13	14.5	87
	F	13	4	Acute suppurative appendicitis	+	10	14.3	77
II	M	18	1	Acute suppurative appendicitis	–	7	12.7	NA
	M	18	2	Acute suppurative appendicitis	–	7	15.6	77
	M	19	3	Acute suppurative appendicitis	–	5	7.3	NA
	M	20	4	Acute suppurative appendicitis	–	5	11.5	87
	M	20	5	Acute suppurative appendicitis	–	7	13.8	77
	M	21	6	Acute suppurative appendicitis	–	8	31.2	90
	M	21	7	Acute suppurative appendicitis	–	20	5.6	84
	M	23	8	Acute suppurative appendicitis	+	8	14	81
	M	29	9	Acute suppurative appendicitis	–	10	14.2	82
	M	30	10	Acute appendicitis	–	10	16	58
	M	35	11	Acute suppurative appendicitis	–	NA	NA	NA
	M	38	12	Acute suppurative appendicitis	–	10	17.9	84
	F	18	1	Acute appendicitis	–	6	22.3	86
	F	19	2	Acute suppurative appendicitis	–	6	14.8	78
	F	20	3	Acute suppurative appendicitis	–	20	21.6	83
	F	21	4	Acute appendicitis	–	10	10.8	79
	F	22	5	Acute suppurative appendicitis	–	5	NA	NA
	F	23	6	Acute appendicitis	–	7	15.7	67
	F	25	7	Acute appendicitis	–	5	17.9	77
	F	25	8	Acute suppurative appendicitis	–	10	19.7	87
	F	27	9	Acute suppurative appendicitis	+	10	10.3	72
	F	28	10	Acute suppurative appendicitis	–	10	16	58
	F	35	11	Acute appendicitis	–	8	16	58
	F	37	12	Acute appendicitis	–	7	11.4	89
	F	40	13	Acute appendicitis	–	7	7.7	81
	F	43	14	Acute suppurative appendicitis	–	NA	NA	NA
	F	44	15	Acute suppurative appendicitis	–	10	11.5	80
III	M	48	1	Acute suppurative appendicitis	–	10	22.8	94
	M	49	2	Acute appendicitis	–	7	15.2	90
	M	53	3	Acute appendicitis	–	6	14.6	76
	M	55	4	Acute suppurative appendicitis	–	NA	14	86
	F	51	1	Acute appendicitis	–	10	15.4	91
	F	53	2	Early appendicitis	–	6	8.6	79
IV	M	62	1	Acute suppurative appendicitis	+	10	15	81
	M	67	2	Acute suppurative appendicitis	–	20	15.7	67
	M	67	3	Acute suppurative appendicitis	–	NA	NA	NA
	F	62	1	Acute suppurative appendicitis	–	10	10.8	81
	F	76	2	Acute suppurative appendicitis	–	10	14.7	87
	F	87	3	Acute suppurative appendicitis	–	NA	NA	NA

N/L ratio = neutrophil/lymphocyte ratio; WBC = white blood cell; NA = not available.

Table 5. Comparison of ultrasonographic diagnosis of acute appendicitis (AA) of the current study and previous studies

First author, year [reference no.]	Total	AA	Prevalence (%)	Sn (%)	Sp (%)	PPR (%)	NPR (%)	Ac (%)
Puylaert JBCM, 1986 [1]	60	28	46.7	89	100	89	91	95
Abu-Yousef MM, 1987 [3]	68	25	36.8	80	95	91	89	90
Jeffrey RB Jr, 1987 [4]	90	30	33.3	89	95	NA	NA	93
Jeffrey RB Jr, 1988 [5]	250	89	35.6	89.9	96.2	93	94.3	93.9
Adams DH, 1988 [6]	44	22	50	89	86	84	90	87
Kang WM, 1989 [7]	62	42	67.7	85.7	100	NA	NA	90.3
Vignault F, 1990 [8]*	70	33	47.1	94	89	NA	NA	91
Schwerk WB, 1990 [9]	857	194	22.6	89.7	98.2	93.6	97	96.3
Chen JJ, 1991 [10]	66	32	48.5	71.9	88.2	85.2	76.9	80.3
Wong ML, 1994 [11]*	93	24	25.8	86.2	98.4	96.2	93.4	94.5
Tiu CM, 1995 [12]	221	52	23.5	84.6	97.6	95.6	90.9	92.5
Ramachandran P, 1996 [13]	452	112	24.8	90	96	NA	NA	95
Zielke A, 1997 [14]	504	113	22.4	83.1	96.6	87.9	95.2	93.6
Hahn HB, 1998 [15]*	3,859	494	13	90	97	82	98	96
Current study	734	351	48	87	90	89	88	89

*Study of children. AA = number of surgically proven acute appendicitis cases; Ac = accuracy; NA = not available; prevalence = number of surgically proven acute appendicitis cases/total number of performed sonograms. See Table 1 for calculations of sensitivity (Sn), specificity (Sp), positive predictive rate (PPR), negative predictive rate (NPR) and diagnostic accuracy (DA).

48%), of which HRUS results were positive in 306 patients (sensitivity, 87%). Among the 383 patients without acute appendicitis, true negative results on HRUS were obtained in 345 patients (specificity, 90%), for which the true conditions were proven surgically in 45 patients and monitored clinically in 300 patients. The overall diagnostic accuracy, and positive predictive and negative predictive rates of HRUS were 89%, 89% and 88%, respectively.

Of the 351 patients with acute appendicitis, perforation of the appendix occurred in 113 (perforation rate, 32%). HRUS successfully detected 98 of 113 (87%) patients with perforation of the appendix. Two peaks of high perforation rate were obtained: one in age group I, and one in age group IV. Similar results were disclosed between male and female patients.

Excluding the 113 patients with perforated appendicitis, the sensitivity, specificity, diagnostic accuracy, positive predictive and negative predictive rates of HRUS in 621 patients were 87%, 90%, 89%, 85% and 92%, respectively, showing no statistically significant differences with the total patient group. The negative appendectomy rate (patients not ultimately requiring appendectomy) was 19% (83 of 434 patients).

Statistically significant differences in sensitivity, positive predictive rate and accuracy, were revealed in several of the subgroups. In age group II, the sensitivity and positive predictive rate of HRUS were significantly higher in males than in females ($p < 0.05$). In age group III, the accuracy of HRUS was statistically significantly higher in women than in men ($p < 0.05$). Among women, the accuracy was significantly higher in group III than group II ($p < 0.05$). Among men, there was no statistically significant difference in accuracy among the different age groups.

There were 38 false-positive and 45 false-negative results out of 734 sonographic studies. Of the 38 patients who were false-positively diagnosed with acute appendicitis sonographically, five patients belonged to age group I (one boy and four girls), 29 belonged to group II (14 men and 15 women), one belonged group III (man), and three belonged to group IV (one man and two women). The details of the pathological results of the appendix in these 38 patients and concurrent pathological findings of adjacent structures are summarized in Table 3. Histologically, diagnosis of acute appendicitis was based on the finding of polymorphonuclear cell infiltration of the entire appendiceal wall. The pres-

ence of fecalith, lymphoid hyperplasia, congestion and periappendicitis did not lead to the diagnosis of acute appendicitis. In our study, 31 of 38 patients had either lymphoid hyperplasia or fecaliths in the appendiceal lumen, or both. Periappendicitis was diagnosed in five patients. Congestion and mucinous cystadenocarcinoma were found in one patient each. The diameter of the resected appendix was recorded in 30 patients, and ranged from 4 mm to 12 mm, with an average of 7.1 mm. The blood WBC count was recorded in 36 cases and ranged from 6,200/μL to 28,800/μL, with an average of 11,922/μL. The percentage of neutrophils was recorded in 32 patients and ranged from 43% to 89%, with an average of 75%. Among these 38 cases, three patients had tumors (lymphoma of the terminal ileum, endometrioma of the right ovary and tumor of the ascending colon near the ileocecal valve) and eight cases were due to inflammation of adjacent structures. The inflammatory processes included cecal diverticulitis in three cases, cecal serositis in one, mesenteric adenitis in one, periappendiceal abscess due to fishbone retention and perforation of the terminal ileum in one, pelvic inflammatory disease in one and chronic cholecystitis with acute onset and perforation in one. In five patients with periappendicitis, four (80%) had blood WBC counts higher than 10,000/μL and neutrophils of greater than 80%. The appendix specimens measured 5 mm in diameter in three cases and 12 mm in two cases. Of those five cases, three were associated with periappendiceal abscess, cecal diverticulitis and right ovarian endometrioma as mentioned above. Of 734 patients, there was only one case of appendiceal carcinoma, for an incidence of 0.14% of all patients undergoing sonographic study and 0.23% of all surgically proven appendicitis cases. For patients in age group IV, the incidence of appendiceal carcinoma was 1.1% of all studied cases and 1.8% of all surgical cases.

The age- and sex-specific results of the false-positive sonographic results were as follows. In age group I, there was one patient with fecalith among boys and four patients with lymphoid hyperplasia among girls. In age group II, fecaliths, lymphoid hyperplasia and periappendicitis were seen in five, seven and two men, and in six, seven and three women, respectively. One woman in age group II had congestion of the appendix. In age group III, lymphoid hyperplasia was found in the only man with a false-positive result. In age group IV, lymphoid hyperplasia was noted in one man and one woman, while appendiceal carcinoma was evident in only one woman.

Among the 45 cases of false-negative sonographic results, there were six patients (two boys and four girls) in age group I, 27 (12 men and 15 women) in group II, six (four men and two women) in group III, and six (three men and three women) in group IV. None of these patients met the sonographic criteria established to diagnose acute appendicitis at the time of sonographic study. The details of these patients, including the pathologic results, diameter of the appendix, and white blood cell (WBC) count and percentage of neutrophils are further summarized in Table 4. After surgical resection, the diameter of the appendix was less than 7 mm in nine patients (22.5%) and equal to or larger than 7 mm in 31 patients (77.5%). In five patients, the diameter of the appendix was not recorded. The average diameter recorded among 40 patients was 9.1 mm and ranged from 5 mm to 20 mm. The WBC count was less than 15,000/μL in 21 patients (52.5%) and was equal to or greater than 15,000/μL in 19 patients (47.5%). The average WBC count in recorded 40 patients was 15,355/μL, ranging from 5,600/μL to 31,200/μL. In thirty-eight of the 45 patients, the percentage of neutrophils was recorded. The neutrophils were less than 80% of WBCs in 14 patients (37%) and were equal to or greater than 80% in 24 patients (63%).

Comparison of 15 sonographic studies (14 previously reported studies and ours) of acute appendicitis showed a negative correlation between the negative predictive rate of sonographic diagnosis and the prevalence of acute appendicitis (correlation coefficient = –0.724, $p = 0.012$), and between the overall accuracy and the prevalence of acute appendicitis (correlation coefficient = –0.611, $p = 0.016$).

Discussion

Being the vermiform continuation of the cecum, the appendix arises from the posteromedial aspect of the cecum distal to the terminal ileum, and may locate medially, caudally, laterally or retrocecally [16]. Because of the different possible locations of the appendix, inflammation of the appendix and pathology of adjacent structures may mimic each other, thus making it difficult to diagnose acute appendicitis clinically. In 1994, Lin et al reported 427 cases

of appendectomy with a clinical diagnosis of acute appendicitis [17]. In their report, an accurate diagnosis of acute appendicitis was achieved in only 71% of patients (76% in men, 65% in women), and it was even lower in women of childbearing age, accounting for only 59% of these women.

The application of sonography for the diagnosis of acute appendicitis was first introduced in 1986, when Puylaert and colleagues reported the ultrasonographic evaluation of acute appendix in 60 cases using a graded compression technique with an accuracy of 95% [1]. The sonographic diagnosis of acute appendicitis in their report was based on visualization of a noncompressible, aperistaltic, tubular structure with one blind end in the right lower quadrant. In 1987, Jeffrey et al considered the visualization of an appendix greater than 6 mm in diameter in adult patients with persistent right lower quadrant pain as the sonographic criterium of acute appendicitis [4]. Thereafter, reported accuracy rates for sonographic diagnosis of acute appendicitis have ranged from 77% to 96% [3–15, 18–22]. However, the relationship between the prevalence and sonographic results of acute appendicitis has not been previously documented.

The prevalence of acute appendicitis and results of sonographic diagnoses in our study and those of 14 other documented studies, in which sonographic diagnosis of acute appendicitis was analyzed for case numbers over 40 [1, 3–15], were compared. In Table 5, total number of clinically suspected acute appendicitis cases examined by sonography, number of pathologically proven acute appendicitis cases and prevalence of acute appendicitis (defined as the ratio of the number of pathologically proven acute appendicitis cases divided by the number of clinically suspected acute appendicitis cases examined by sonography) are recorded. Additionally, results of sonographic diagnosis of acute appendicitis including sensitivity, specificity, positive predictive value, negative predictive value and diagnostic accuracy are shown. The prevalence of acute appendicitis in the previous reports ranged from 13% [20] to 68% [8]. There is a negative correlation between the negative predictive rate of sonography and the prevalence of acute appendicitis, and between the overall accuracy and the prevalence of acute appendicitis. This result depicts how the prevalence influences the sonographic evaluation of clinically suspected appendicitis. A lower prevalence (a small number of pathologically proven acute appendicitis cases with a large number of clinically suspected acute appendicitis cases) of acute appendicitis will result in a higher negative predictive rate and accuracy of sonographic results in diagnosing acute appendicitis.

It was difficult to determine the reason for the false-negative results in 45 of our patients because they underwent appendectomy without a second sonographic evaluation. The possible reasons for false-negative sonographic results were classified into three different categories. First, inflammation of the appendix was in the early stage and the appendix was not swollen enough (i.e., diameter < 7 mm) as was seen in nine patients. Second, the appendix was swollen and equal to or larger than 7 mm in diameter, but was overlooked by the sonographer, as was evident in 26 patients. Third, the appendix might have been less than 7 mm in diameter at the time of sonography, but progressively enlarged after sonography, which prompted surgical intervention. All of these factors might have led to false-negative sonographic results in the statistical calculation.

Several factors, including bowel gas interference, unusual location of the appendix, obesity and/or early stage of appendicitis, might also contribute to false-negative results. Obesity may increase the distance between the probe and the appendix and may result in inadequate compression of the bowel gas, both causing difficulty in detecting the inflamed appendix. It is even worse when the appendix is deeply seated or is retrocecal in position. In our department, residents receive 3 months of training in the sonographic center before independently performing sonography for acute appendicitis. Because sonography is an operator-dependent imaging study, an inexperienced sonographer may overlook acute appendicitis due to inadequate compression of gas-filled bowel loops, especially in obese or uncooperative patients.

Were the results of sonographic diagnosis of acute appendicitis different regarding different age and sex subgroups? By dividing our patients into four age subgroups and two gender subgroups, we found a diversity of HRUS results in diagnosing acute appendicitis. First, the sensitivity and positive predictive rate were much higher in males than in females in age group II (18–45 yr) ($p < 0.05$). In our study, there were two false-positive results

due to gynecologic problems — pelvic inflammatory disease in one case and right ovarian endometrioma in another. This lowered the sensitivity of HRUS among females. The positive predictive rate was influenced by true-positive and false-positive results. The actual reasons for false-positive results were difficult to verify in this study because these patients did not have a re-check HRUS before surgery. Second, the overall accuracy of HRUS in age group III was much higher in women (96%) than in men (86%, $p < 0.05$). It was due to more false positive and false negative results in men (false positive in 1 and false negative in 4) than in women (no false positive, 2 false negative) and the relatively small number of total cases (37 in men and 53 in women). Finally, higher overall accuracy was obtained in women in age group III (96%) than in those in age group II (85%, $p < 0.05$).

For age group I, sensitivity, specificity, positive predictive rate, negative predictive rate and overall diagnostic accuracy were higher in males than in females. On the contrary, all of these values were higher in women than in men in age group III. No statistically significant difference in the above-mentioned groups was found.

Conclusion

In conclusion, negative predictive value and accuracy of HRUS for the diagnosis of acute appendicitis did not correlate with the prevalence of acute appendicitis; the negative predictive value and accuracy decreased as the prevalence of acute appendicitis increased. The sonographic diagnosis of acute appendicitis differed by age and sex. Women of childbearing age (18–45 yr) had lower sensitivity and positive predictive rates than did men in the same age group. Accuracy was higher overall in women 46 to 60 years of age than in men. Among women, higher overall accuracy was obtained in the childbearing age group than in women 46 to 60 years of age.

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